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Non-invasive assessment of isolated atrial defects

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SUMMARY This study attempts to predict the size of shunt in secundum atrial septal defects by non-invasive M-mode echocardiography.

The areas under the excursions of the mitral and tricuspid valves were measured with a sonic digitiser and the ratio of these areas compared with the shunt size as obtained at catheterisation. The relation between the mitral and tricuspid valve areas in patients with atrial septal defect is significantly different from that in healthy subjects. There is a significant positive correlation between the ratio of mitral and tricuspid valve areas and the shunt size.

Solitary secundum atrial septal defect with a left to right shunt and no other congenital abnormality or complication is a common condition. Clinical hallmarks of atrial septal defect are well recognised, and by other simple non-invasive methods it is usually possible to isolate this condition. In the age range 3 to 30 years, complications are rare and, with the possible exception of anomalous pulmonary venous drainage, associated congenital abnormalities and variants are recognisable. The assessment of shunt size is *the*, if questionable, indication for cardiac catheterisation.

The size of high pressure left to right shunts—ventricular septal defects and persistent ductus arteriosus—has been successfully predicted by the aortic/left atrial ratio as measured on the M-mode echocardiogram.[1 2] This technique has also been used in controlling the size of the ductus as well as monitoring postoperatively closures of ventricular septal defect. The patients with atrial septal defect, however, show no left atrial enlargement because the volume overload is immediately shunted into the right atrium and the aortic/left atrial ratio becomes invalid.

Two typical characteristics of atrial septal defect suggest a possible method of assessing the size of the left to right shunt. The first is that the tricuspid valve and mitral valve are both easily shown by M-mode echocardiography. Secondly, it has been shown that the stroke volume is related to the area beneath the mitral valve cusps.[3] We have based this paper on the hypothesis that the pattern of mitral valve and tricuspid valve echocardiograms would reflect the quantity of blood traversing each valve with each heart beat, and the ratios of these areas will be the shunt size.[4]

Subjects and methods

Fifty-nine male and female patients with simple uncomplicated secundum atrial septal defect, in the age range 7 months to 67 years, underwent cardiac catheterisation. These patients, together with 60 healthy control subjects in the age range 4 to 33 years, were investigated by M-mode echocardiography. All recordings were made using a Smith Kline (SKI) Ekoline 20A interfaced with an Ekoline 21 strip-chart recorder using SKI 2·25 and 5·0 MHz focused and non-focused cardiac transducers. For the echocardiographic examinations the subjects were placed supine or in a left lateral position, the head and thorax raised to approximately 20°. Initially the transducer was placed close to the left sternal border in the third or fourth intercostal space to locate the mitral valve. The location of the anterior tricuspid valve leaflet was usually made from the initial location of the aortic root. To check more closely the anatomical relation of the tricuspid valve to the mitral valve the transducer was angled from a medial to a lateral position. Only M-mode echoes with well-defined mitral and tricuspid tracings were accepted for measurement. Because the posterior cusp of the tricuspid valve, even in atrial septal defect, is difficult to define, we measured only the area under the anterior cusp in both valves as an index of blood flow. The take-off point of the anterior cusp was easy to identify. The boundaries of the measured area were the anterior cusp in front and behind a straight line from the take-off point of the anterior cusp parallel to the

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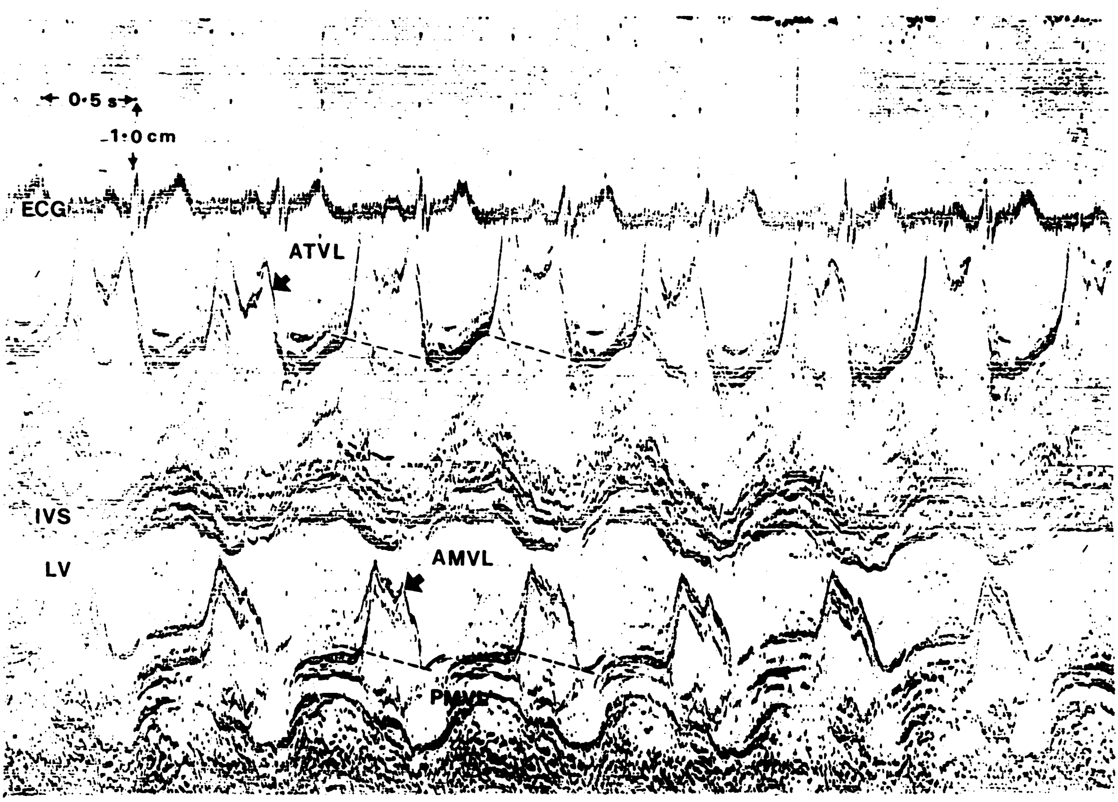

Fig. 1 *Composite echogram, in phase, from a single M-mode tracing of tricuspid and mitral valve, illustrating the points from where the areas under the anterior cusps were measured, using a sonic digitiser.*

movement of the fibrous skeleton. The area was completed at its intersection with the returning anterior cusp at end-diastole (Fig. 1). These areas under the valve tracing were measured using a sonic digitiser (Graf-Pen) which gave an integrated value in cm s. These values, time-distance indices, were then standardised, by (a) correcting for depth and (b) correcting for time the valves were open. Time standardisation was considered necessary because flow occurs mainly in the first part of diastole and also during atrial systole. In between, the direction of flow oscillates.

In order to arrive at a statistically acceptable number of valve areas to be measured, we used the estimate of our population standard deviation σ in the following equation[5]

$$n = 4\,\sigma^2/\epsilon^2$$

where ϵ is the allowable error in the sample mean of $\pm 0{\cdot}2$ cm s.

For this study it gives: $n = \dfrac{0{\cdot}4284}{0{\cdot}04} = 10{\cdot}71$

Therefore, to be reasonably certain (95% confidence limits) that the error will not exceed ϵ, we have measured 11 valve excursions.

The shunt size was calculated from O_2 saturations based on the Fick principle:

$$Qp{:}Qs = \frac{1}{\text{AV } O_2 \text{ difference}} : \frac{1}{\text{PV } O_2 - \text{PA } O_2}$$

Right heart blood samples were obtained from routine sites, that is high superior vena cava immediately below the junction of the brachiocephalic vein; low superior vena cava proximal to the junction of the azygos vein; high, mid, and low cavity right atrium; high inferior vena cava between the renal and hepatic veins; low inferior vena cava below the entrance of the renal veins. Left heart samples were obtained from the ascending aorta and left ventricle. One blood sample was taken from each site and analysed for O_2 saturation using a Miniphotometric (Compur M1000) oximeter. In all patients, National Institute of Health (NIH) No. 6 to 8 and occasionally Cournand No. 8 disposable catheters were used.

Table *Range, mean, and standard deviation values of variables for healthy control group and patients with atrial septal defect*

Variables	*Healthy control group (n=60)*			*Patients with atrial septal defect (n=59)*		
	Range	*Mean*	*SD*	*Range*	*Mean*	*SD*
Age (y)	4·0 – 33·0	17·4	±11·6	0·58 – 67·0	24·3	±18·9
ATVL (cm s)	2·80 – 7·26	5·14	± 0·99	2·90 – 15·49	7·98	± 3·15
AMVL (cm s)	3·27 – 7·07	5·25	± 1·00	2·66 – 9·37	4·82	± 1·45
TV/MV area (ratio)	0·86:1 – 1·03:1	0·98:1	± 0·36:1	0·84:1 – 2·64:1	1·67:1	± 0·47:1
Shunt size (ratio)	–	–	–	1·46:1 – 5·4:1	2·76:1	± 0·95:1

Plain chest x-ray films of the heart and full electrocardiographic recordings were taken. Pulmonary plethora and pulmonary trunk size were quantified subjectively in four numerical grades (1 to 4) representing minimal, moderate, severe, and gross.

Results

The Table shows the range, mean, and standard deviations for age and the measured variables for the two groups of subjects. The regression of standardised anterior mitral valve leaflet (AMVL) areas on anterior tricuspid valve leaflet (ATVL) areas was calculated; the equations are as follows.

Healthy subjects

AMVL (Y)=0·275+0·968XSEE±0·27 r=0·96

Patients with atrial septal defect

AMVL (Y)=2·428+0·303XSEE±1·1 r=0·65

Analysis of covariance shows that the regression coefficients and the constant terms are significantly different from one another (F=72·5 and 36·7, respectively).

Fig. 2 shows the regression of shunt size, as measured at cardiac catheterisation, on ATVL/AMVL area ratio in patients with atrial septal defect. This relation has a correlation coefficient of r=0·89 with an SEE of ±0·44.

The bar chart for five related variables to the prediction of shunt size in isolated atrial septal defect is shown in Fig. 3 in comparative correlation. It can be seen that echocardiogram tricuspid valve/mitral valve area is effectively twice as good a predictor as pulmonary plethora, its nearest rival.

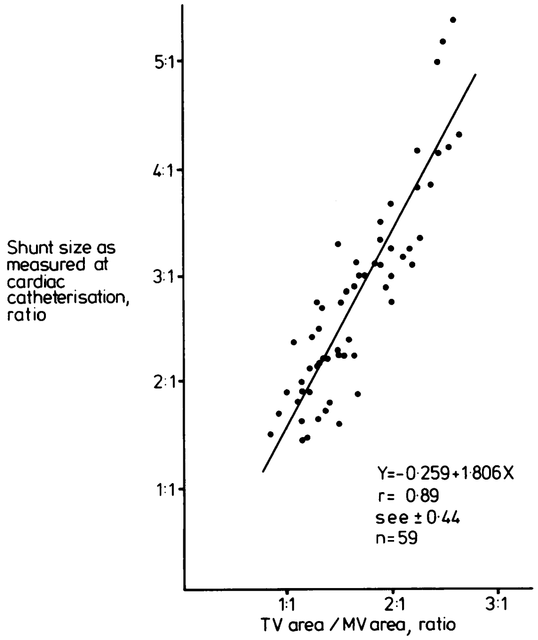

Fig. 2 *The regression relation between the ratios of shunt size, as measured at cardiac catheterisation, and ATVL/AMVL areas, measured from M-mode echocardiography, in 59 patients with atrial septal defect.*

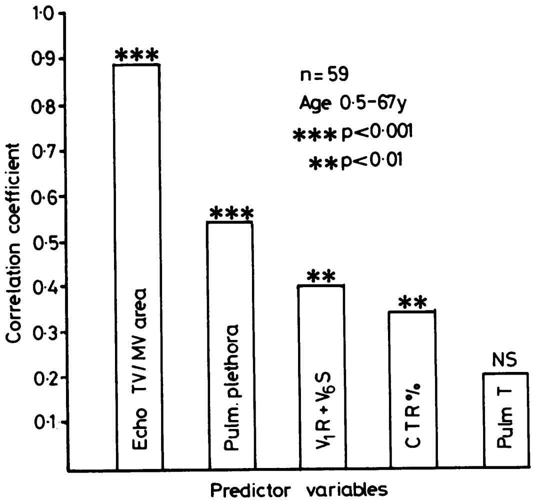

Fig. 3 *Bar chart showing the differing levels of correlation and significance for the prediction of shunt size from five non-invasive related variables in 59 patients with atrial septal defect.*

Discussion

Subjects with right ventricular volume overload such as secundum atrial septal defect differ from normal subjects in that both mitral and tricuspid valves are readily seen in the M-mode record. The valves differ significantly in respect to the area within the diastolic excursion and this is predictable from the regression equations. This difference has been established in healthy control subjects and, using it as a base, and assuming that in the healthy the flow through the two valves is equal, then a change in this relation indicates a different flow in the two valves, and it, therefore, has been used to predict shunt size. While the clinical diagnosis of this condition is relatively simple, prediction of the size of the shunt by non-invasive methods has proved difficult. With the possible exception of pulmonary plethora, a notoriously subjective assessment, and the electrocardiograph measurement V1R+V6S, good prediction of shunt size has not been possible (Fig. 3).

By showing the mitral and tricuspid valves and measuring the area beneath the anterior cusp of each, a comparison with the normal tricuspid valve/mitral valve relation has made it possible to predict a shunt that correlates well with that calculated from percentage O_2 saturations at cardiac catheterisation. This correlation coefficient is 0·89 and accounts for nearly 80% of the variance; it allows the pulmonary systemic flow ratio (Qp/Qs) to be predicted with an accuracy well within the requirements of clinical practice, that is Qp/Qs$\pm$0·44.

The method is offered as a practical basis for the decision not to operate on patients with secundum atrial septal defects that are considered clinically to be small.

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